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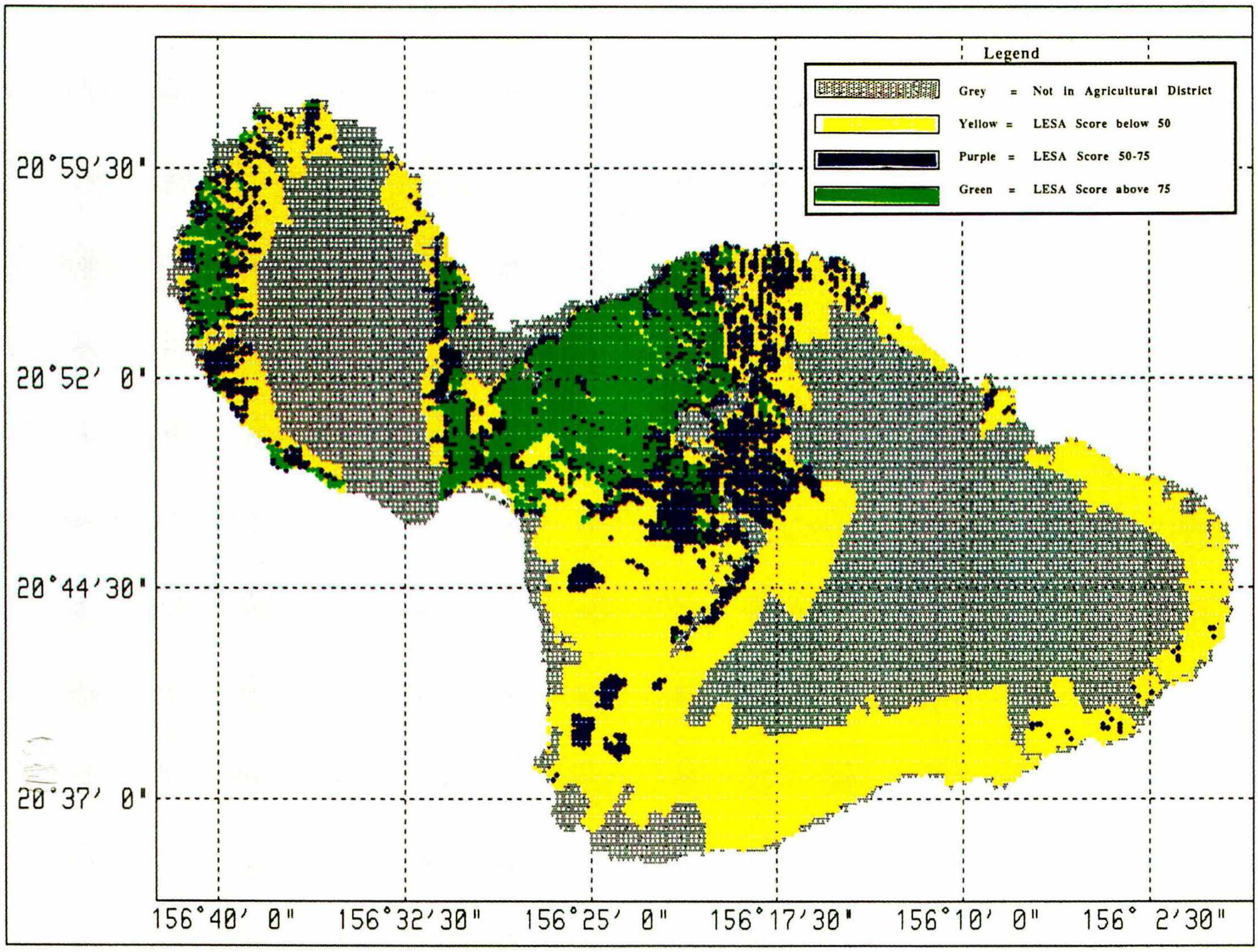
An Appraisal of the Hawaii Land Evaluation and Site Assessment (LESA) System



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ABSTRACT

In 1986, the Hawaii Land Evaluation and Site Assessment (LESA) Commission specified a LESA system to rate the agricultural suitability of land parcels and to identify Important Agricultural Lands (IAL) within the state. The Commission also made recommendations on the system's use for state zoning and other reforms of Hawaii's Land Use Law. Subsequent legislation directed development of a state LESA system and production of LESA maps. This bulletin reviews the Land Use Law, the LESA Commission's findings, and the LESA methodology. Implementation of the Hawaii LESA system within a Geographic Information System (GIS) is described, including the problems encountered during its development. LESA scores of agricultural land and the IAL identified by the system are shown in colored maps for six major islands. Issues which have arisen in the state legislature since the LESA Commission's report are discussed. The suitability of the LESA-GIS for state zoning is examined against the experience gained during system development, and the results of statistical analysis of Oahu LESA scores. Several modifications of the existing system are recommended, especially the clarification of Site Assessment factor definitions and the deletion of marginal factors from the mapped system.

I. INTRODUCTION

State and local governments across the United States have enacted land use legislation to preserve, sustain and protect agriculture (Klein, 1982; Meeks, 1984). Concerns motivating agricultural land protection include: providing sufficient food and fiber for future generations; maintaining a viable agriculture industry; limiting the undesirable effects of urbanization; and preserving environmental quality.

State and local governments have developed a variety of policies to protect agricultural lands. These policies can be grouped into five general categories: acquisition of property rights; preferential taxation of property; legal protection; indirect government programs; and zoning. State and local governments have moved to more integrated agricultural protection techniques with the realization that no single technique can provide adequate protection (Bushwick and Hiemstra, 1987).

Zoning is the technique upon which Hawaii most heavily relies for protection of agricultural lands. Agricultural zoning provides governments a low cost and straightforward method of land use protection. Hawaii was the first state to initiate statewide zoning, in large part due to a concern for protecting agricultural lands from excessive speculation (DeGrove, 1984).

This report focuses on the technical aspects of implementing Land Evaluation and Site Assessment (LESA), an agricultural land rating system, as a tool for improved statewide zoning in Hawaii. The report documents the lessons learned in developing a statewide, computerized LESA mapping system and assesses the LESA rating scheme using mapped Oahu data.

The use of LESA for proposed reform of Hawaii's land use regulatory system is explored through several case studies on Oahu. These case studies reveal potential problems in implementation, and other shortcomings which must be overcome either by legislation or by agencies given the responsibility for using LESA. As such, the research results can be used to improve the technical aspects of LESA implementation.

In assessing the potential use of the Hawaii LESA system, it is important to distinguish between LESA, a method of rating land for agricultural suitability, and LESA-related legislation, intended to provide greater protection for Hawaii's Important Agricultural Lands. Whether LESA-related reforms will provide greater protection for Hawaii's Important Agricultural Lands against urbanization pressures is beyond the scope of this study. LESA is a tool designed to reflect an agricultural perspective, whereas land use issues are resolved in a broader decision-making context. Yet, improved technical analysis, interpreted properly, will likely result in better land use decisions.

II. HAWAII'S LAND USE LAW AND THE LESA COMMISSION

At the county level, Hawaii's zoning system is similar to those of most American cities. But Hawaii is unique in having a statewide system of zoning, created in 1961 by passage of the Hawaii Land Use Law. This law added an additional layer of zoning authority, in response to the perception of county irresponsibility regarding scattered development threatening agricultural land (DeGrove, 1984).

Under the present law, all land in the state is classified into four districts—Conservation, Agricultural, Rural, and Urban. Changes in district boundaries can be petitioned by state or county government agencies, or by property owners or lessees, and must be approved by the state Land Use Commission (LUC). The state Board of Land and Natural Resources regulates land uses in the Conservation District. The county governments regulate land uses in the Urban Districts. Land uses in the Agricultural and Rural Districts are jointly administered by the counties and the state LUC. The classification and districting of all lands are subject to review every five years.

The distribution of land, by island, within each of the land use districts is shown in Table 1. The Conservation District, consisting of land necessary for protecting watersheds, water sources and for other conservation purposes, contains 48 percent of Hawaii's 4.1 million acres. The Agricultural District contains land highly suited to farming, as well as land which does not qualify for inclusion in the other three districts. The Agricultural District is therefore a "residual" district that contains an amount of land similar to the Conservation District. The Rural District consists of small, half-acre "rural" lots and contains only 0.2 percent of the state's land area. The Urban District consists of lands that are presently in urban uses and those lands reserved for foreseeable urban growth. Only 4 percent of Hawaii's lands are in the Urban District.

Table 1. Estimated Size of Land Use Districts by Island, 1988

Island	Land Use District				
	Agriculture	Rural	Urban	Conservation	Total(a)
			1000s acres (% island total)		
Hawaii	1,230.0 (48%)	0.6 *	41.8 (2%)	1,300.9 (51%)	2,573.4
Kauai	141.5 (40%)	1.2 *	12.4 (4%)	198.7 (56%)	353.9
Lanai	47.2 (52%)	2.7 (3%)	2.3 (3%)	38.2 (42%)	90.5
Maui	251.3 (54%)	3.7 *	17.1 (4%)	193.7 (42%)	465.8
Molokai	111.7 (67%)	1.9 (1%)	2.5 (2%)	49.8 (30%)	165.8
Oahu	141.9 (37%)	0.0 (0%)	89.4 (23%)	154.9 (40%)	386.2
Other (b)	45.7 (60%)	0.0 (0%)	0.0 (0%)	31.1 (40%)	76.8
State (a) Total	1,969.3 (48%)	10.2 *	165.6 (4%)	1,967.2 (48%)	4,112.4

* = less than 1% (a) May not add up due to rounding. (b) Niihau, Kahoolawe, Kalua, Lehua, and Northwestern Hawaiian Islands.

Source: DBED(1988).

The island of Hawaii has the largest amount of land in the Agricultural District, with 1.2 million acres. Molokai has the largest proportion, with 67 percent of its land in the Agricultural District. At least one third of the land on each island is presently in the Agricultural District

In 1978, the people of Hawaii amended the Hawaii State Constitution to require the state legislature to provide standards and criteria "...to conserve and protect agricultural lands, to promote diversified agriculture, increase agricultural self-sufficiency and to assure the availability of agriculturally suitable lands..." To implement this constitutional mandate, the Hawaii legislature established a two-year study commission. The Commission's purpose was to identify "Important Agricultural Lands" (IAL) that the legislature should set aside and protect from conversion to urban uses. The IAL were to be identified according to a Land Evaluation and Site Assessment (LESA) classification system to be developed by the Commission.

Guidelines for developing the Hawaii LESA system were provided by the legislature. The LESA Commission was to first evaluate and recommend a set of agricultural production goals for the state, based on economic feasibility and the identification of specific locational and land area requirements to attain these goals. The Commission was also directed to prepare a set of maps identifying the IAL and to propose legislation to implement recommended land use reforms.

In its report, the LESA Commission proposed a major reform of the state Land Use Law based on the Hawaii LESA system. The Commission held that better protection could be given to good agricultural land by forming a new Agricultural District which would exclude poor agricultural land. The Commission recommended that the size of the Agricultural District be reduced from nearly two million acres to less than 700,000 acres.

The Commission also recommended a major change in jurisdictional control of lands in Hawaii, placing the excluded Agricultural District lands under the control of the counties. The new Agricultural, or IAL, District would be regulated much as it is today, with the state Department of Agriculture taking on a greater role in establishing permitted uses and infrastructure standards. The LESA Commission recommended that the LESA classification system, including state production goals and target acreages, be reviewed every five years, or at earlier intervals when warranted.

The report of the LESA Commission was issued in February, 1986.[1] Several bills were introduced that year in the state legislature to implement the recommendations contained in that report. However, due to the lack of maps delineating the proposed IAL and uncertainty as to how the Hawaii LESA classifying system would impact the various counties and communities within the state, all implementing legislation was tabled. Instead, the state legislature provided funding to the Office of State Planning (OSP) to develop computerized maps delineating the proposed IAL, and to analyze how the LESA method of land evaluation would work in practice.

Researchers in the University of Hawaii's College of Tropical Agriculture and Human Resources (CTAHR) were contracted to develop computerized IAL maps and to analyze the LESA methodology. An in-depth report of that research was submitted to OSP in 1989 (Martin, Ferguson and Bowen). This publication summarizes that report and other issues that have surfaced since the termination of the LESA Commission.

III. IDENTIFYING IMPORTANT AGRICULTURAL LANDS

The 1978 state legislature directed the Hawaii LESA Commission to develop a LESA system for identification of the state's Important Agricultural Lands (IAL). This section first reviews the LESA methodology and the system recommended by the Commission. Next, development of a computerized mapped version of the Hawaii LESA system is explained, followed by color maps delineating LESA scores and IAL on six major islands.

Land Evaluation and Site Assessment

The Land Evaluation and Site Assessment (LESA) methodology was developed by the U.S. Department of Agriculture Soil Conservation Service (USDA-SCS) in the early 1980s. The system was initially used to evaluate the impacts of proposed federal projects involving agricultural land conversion. LESA's potential for wider application gained quick recognition. A generalized LESA system was developed for state and local governments to use in formulating and implementing farmland protection and other natural resource development plans or programs (Wright, *et al.*,1983; Steiner, Dunford and Dosdall, 1987).

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[1] A copy is available for public review in the library of the Hawaii Legislative Reference Bureau.

A LESA system is a methodology designed to rate the relative suitability of lands for agricultural use. LESA may be used as the basis for classifying all lands within a given area or to evaluate individual land parcels. Two basic components,"Land Evaluation" and "Site Assessment," comprise a LESA system.

The **Land Evaluation (LE)** component measures agricultural productivity as determined by soils, topography, climate, and other physical factors. It consists of several standard soils-based measures which quantify soil limitations for agricultural use, soil productivity, soil potential for a given indicator crop(s), and/or the importance of certain soil types for specific crops grown within an area. These different measures, termed "LE factors," are used to group soil types. Groups are assigned an LE rating on a 0--100 scale (worst to best) based on crop yield potential. Land Evaluation considerations of economic factors and farm profitability are limited to the costs of overcoming or, if not correctable, continuing soil limitations (Wright, *et al.*, 1983). Used independently, the LE component omits important determinants of agricultural land suitability (*e.g.*, distance to markets, farm size, etc.). [See Wood (1976) for criticisms of such land classification systems.] A total LESA system can accommodate such factors through its second component.

LESA's **Site Assessment (SA)** component assesses agricultural suitability due to the relative location of a parcel and other spatial aspects of land use. SA complements LE's emphasis on physical productivity by bringing into the system additional economic, institutional, and social elements that support farm viability. Like LE, Site Assessment is composed of several factors against which a land parcel is rated by assigning points. SA factor points are aggregated in a weighted average on a scale of 1--100 points for an overall SA score. Typically, the total LE and SA scores are combined at a given LE:SA ratio and rescaled to produce a total LESA score.

Hawaii LESA System

The general LESA model is adaptable to local conditions and purposes through 1) the choice of specific LE and SA factors to be included, 2) the factor weights, and 3) the LE:SA ratio. In addition to Hawaii, four other states (Illinois, Delaware, Utah, and Virginia) have developed or tested LESA systems, and over 46 local governments in 19 states have implemented them (Steiner, Dunford and Dosdall, 1987).

In the 1983 legislation which created the LESA Commission, the Hawaii Legislature provided guidelines for the formulation of an agricultural land classification system for the state. These guidelines included the use and consideration of existing data and studies conducted by the Land Study Bureau of the University of Hawaii (UH-LSB), the Agricultural Lands of Importance to the State of Hawaii (ALISH), and the U.S.Department of Agriculture Soil Conservation Service's (USDA-SCS) Land Evaluation and Site Assessment System. The standards, criteria, and procedures of the national LESA system were evaluated and adapted to the local situation by the Hawaii LESA Commission. The factors and weights deemed important to the unique land setting in Hawaii were selected from the national LESA system.

The LE component of Hawaii's LESA system utilizes five factors from the following soil evaluation systems available to the state (system developer given in parentheses):

(1) Land Capability Classification (USDA-SCS);
(2) Agricultural Lands of Importance to the State of Hawaii (Hawaii Department of Agriculture);
(3) Modified Storie Index (USDA-SCS);
(4) Soil Potential Index (USDA-SCS); and
(5) Overall Productivity Rating (UH-LSB).

As measures of agricultural productivity, the five systems are similar in that all include soil properties and climate as a major part of their evaluation. The main differences between these systems are the extent to which other land attributes (e.g., topography), crop yields and costs are directly considered. The Appendix provides a brief description of the different systems.

In the Hawaii LESA system, the five LE facors are aggregated using a weighted average. The LESA Commission believed that the last two factors listed above, which rate land with respect to specific crops,[2] were more direct measures of productivity, and thereby accorded them a weight of 1.5. The other three factors each received a weight of 1.0

[2] In the Soil Potential Index (SPI), sugarcane is used as the indicator crop for Oahu, Kauai, and Maui. In addition to sugar, the index rates different areas on the Big Island of Hawaii for cabbage, papaya, and macadamia. Because of the lack of pineapple production data, there are no SPI ratings for Lanai and Molokai.

The ten SA factors chosen by the LESA Commission are listed in Table 2, along with the definitions used in mapping. Site Assessment factors can be grouped into three categories reflecting different determinants of a site's suitability for agricultural use. The first determinant is farm productivity and profitability, which is represented in the system by the Irrigation, Farm Facilities, Agricultural

Table 2. Site Assessment (SA) Factor Definitions and Weights

Factor	LESA Commission Criteria	Mapping Definition (a)	Weight
County Plan	Conformity with county plan/policy	Land use designation in county development plan	15
Irrigation	Irrigation facilities/ services	General irrigated areas	10
Urban Facilities	Proximity to urban infrastructure	Linear distance from Urban District	7
Farm Facilities	On-site agricultural improvements	Intensity of 1982 agricultural land use	7
State Programs	Conformity with state agricultural programs/ projects	State government land ownership	7
Agricultural Services	Access to agricultural facilities/services	Linear distance from harbor	4
Farm Layout	Efficiency of farm size, location, configuration	Parcel size	4
Compatible Use	Compatible agricultural land uses within region	Similarity of land use within contiguous 100 acres	4
Drainage	Adequacy of off-site drainage	Flood hazard area	1
Non-Agricultural Use	Impact of nearby non-agricultural use	Extent of non-agricultural use special permits	1

(a) SA factor ratings for mapped definitions given in Table A.1.

Source: LESA Commission criteria and weights from LESAC (1986). Mapping definitions were developed by the authors, Hawaii Office of State Planning and Hawaii State Department of Agriculture.

Services, and Farm Layout factors. The next four factors—Urban Facilities, Compatible Use, Drainage, Non-Agricultural Use—relate to the site's potential for conflict with adjacent lands used for agricultural or other purposes. The remaining SA factors, County Plan and State Programs, assess the conformance of the site's use for agriculture with government programs and policies.

Detailed ratings and points for SA factors are given in Appendix Table A.1. SA factor point scores are combined in a weighted total using the weights shown in Table 2. The total LESA score for the Hawaii system combines the LE and SA ratings at a 1:1 ratio, as recommended by the LESA Commission. This gives greater weight to the physical determinants of agricultural land suitability than the 1:2 ratio recommended in the national LESA handbook (USDA, 1983).

Empirical implementation of the Hawaii LESA system, including preparation of the maps showing the Important Agricultural Lands (IAL), began in 1987. The first step was to identify data sources and collect mapped data for the various system factors. Mapping of the Land Evaluation component was straightforward. Ratings for the five LE factors vary by soil type. Detailed maps were provided by the U.S. Soil Conservation Service.

Development of the Site Assessment component presented greater difficulties. One problem was the LESA Commission factor criteria were not always specified in terms of directly measurable characteristics. For example, the SA factor on compatibility of agricultural land uses within an area and/or region listed three ratings for the following characteristics: fully compatible, partially compatible, and mostly not agriculturally compatible. No description was given for "compatible," nor was the size of the area defined.

A second problem was locating data for all SA factors, particularly in the mapped form needed to identify IAL. For some factors, mapped data were simply unavailable. In other cases, existing maps were of poor quality (e.g., low resolution or outdated), lacked sufficient detail and/or did not fully represent the characteristics in the original criteria. An *ad hoc* committee was formed to revise SA factor criteria and ratings based on the available maps. The committee included representatives from the Hawaii Office of State Planing and Department of Agriculture, as well as the authors. An assessment of the final mapping definitions and data used for Site Assessment is presented in Section V.

Once maps had been collected for the different LESA factors, the data were computerized using a Geographic Information System (GIS). A GIS is computer software especially designed to handle spatial or map information. Computer mapping of the Hawaii LESA system utilized the Hawaii Natural Resources Information System (HNRIS), a GIS previously developed by two of the authors (Liang and Khan, 1986). The Hawaii system was the first statewide GIS application of the LESA methodology.

HNRIS records and stores land use information as lines (vectors) delineating different areas (polygons) on a map. The data are then converted to a grid format, with one entry for a rectangular area 20 acres in size. The geographic locations of land characteristics rated by LESA were entered into HNRIS using a process called digitization.[3] In digitizing a map, the boundaries separating areas with different factor ratings were manually traced from the paper maps onto an electronic table connected to the HNRIS computer. The computer translated a digitized boundary into coordinates, and assigned that rating to grid areas within the boundary.

Besides computerizing map data, GIS technology also allows information from different sources to be combined in an overlay or in mathematical formulas to derive completely new maps. In the Hawaii LESA system, total LESA scores were calculated by the HNRIS computer combining the digitized factor ratings for each grid area with the factor weights and LE:SA ratio. The location of lands having LESA scores within a given range(s) can be viewed in map form on the computer monitor or in paper printouts. The IAL maps presented below were produced by HNRIS.

Delineating Important Agricultural Lands

Target agricultural production acreages for all major islands were specified by the LESA Commission. These targets were developed by analyzing local, national and international market events and trends, and estimating an attainable increase in the level of self-sufficiency under competitive market conditions. Due to uncertainties in the projected target acreages, the LESA Commission increased cropland target acreages by ten percent. Grazing and pasture land estimates were not adjusted. The lands with the highest LESA scores up to targeted acreage amounts are proposed to form the new Agricultural District.

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3 The HNRIS database already contained digitized data for the LE component, so no further data entry was required for LE factors.

Total acreage goals for the state of Hawaii of 678,000 and 689,000 acres for 1990 and 1995, respectively, were indicated by the LESA Commission. These production goals, by crop and by island, are summarized in Table 3. Statewide, the new Agricultural District would be about one third the size of the present Agricultural District.

Table 3. 1990 Important Agricultural Land (IAL) Crop Acreage and IAL Cutoff LESA Scores, by Island

	ISLAND						
CROP	Hawaii	Kauai	Lanai	Maui	Molokai	Oahu	Total
			acres				
Sugar	66,700	41,900	0	46,500	0	25,900	**181,000**
Pineapple	0	0	12,700	9,449	2,100	11,800	**36,049**
Macadamia Nuts	21,250	250	0	3,500	0	0	**25,000**
Coffee	3,600	0	0	0	0	0	**3,600**
Flowers & Nursery	1,420	40	0	370	0	700	**2,530**
Fruit (a)	10,174	1,219	0	453	10	1,160	**13,016**
Vegetables (b)	2,197	764	0	1,694	838	1,601	**7,094**
Aquaculture	525	400	0	75	225	1,500	**2,725**
Cattle, Feed (c)	250,395	20,909	0	70,270	23,466	12,676	**377,724**
Other Animals (d)	258	261	0	176	50	522	**1,267**
Total (e)	**356,519**	**65,743**	**12,700**	**132,495**	**26,689**	**55,895**	**650,005**
Cutoff LESA Scores (f) (maximum 100 points)	**55**	**63**	**75**	**61**	**67**	**71**	

(a) Guava, papaya, banana, other fruits.
(b) Includes melons, taro, seed corn.
(c) Beef/dairy cattle, feed /forage crops. Includes pasture and grazing land.
(d) Eggs, poultry and swine.
(e) Excludes 10% contingency for uses other than grazing or pasture.
(f) Cutoff scores are based on the modified LESA system (4 SA factors).

Source: LESAC (1986).

About half of the state's reformed Agricultural District[4] would be located on the island of Hawaii. Maui island would have the next largest Agricultural District (132,495 acres), followed by Kauai, Oahu, Molokai, and Lanai. Cattle production is by far the largest targeted use, accounting for nearly sixty percent of IAL acreage, followed by sugarcane and pineapple. Export commodities recognized for projected agricultural land needs include aquaculture products, coffee, macadamia nuts, flowers/nursery, guava, papaya, pineapple, and sugar. Local consumption commodities include bananas, beef, dairy products, eggs, feed/forage, fruits, melons, pork and vegetables.

The "cutoff" LESA scores defining the IAL for the 1990 acreage requirements for each island are given in Table 3. For example, the cutoff score for Oahu is 71. All lands with a score of 71 or higher would be placed in the IAL, while lower-scored lands would be excluded from the IAL. Lanai has a higher cutoff score because only pineapple is considered. The lower cutoff score for the island of Hawaii reflects the large amount of extensive grazing lands required to meet production goals.

The reformed Agricultural District was also to include "Unique" Lands, upon which wetland crops (i.e. aquaculture, taro, watercress) and other "unique" commodities can be cultivated. The other unique commodities identified by the LESA Commission are coffee, flowers/nursery, and papaya.

Maps of Important Agricultural Lands

Figures 1–5 present the distribution of LESA scores within the current Agricultural Districts of the six major islands. Because the source maps for all factors on all the islands have not been digitized, the LESA maps presented are based on LE and only the four highest weighted SA factors. Complete maps of Oahu showed only minor differences in the maps based on the complete LESA system versus ones using only the first four SA factors listed in Table 2.

The colored (green, purple, yellow) regions of the maps represent the present Agricultural District. The green regions are lands with LESA scores of over 75; statewide, this includes slightly over 200,000 acres. Many of these lands are present or former sugarcane or pineapple lands. Almost a third (31 percent) of these high-quality lands are located on the island of Maui. The remainder are located on Oahu (21 percent), Kauai (17 percent), Hawaii (16 percent), Molokai (9 percent) and Lanai (6 percent). The present Agricultural District on these individual islands consists of from one fourth to one third of the top-rated lands, with the exception of the island of Hawaii. Only three percent of the Big Island's Agricultural District lands have LESA scores over 75.

The purple regions show areas of land with LESA scores between 75 and the recommended cutoff scores for each island. These medium-quality lands include a large amount of land previously used to produce sugarcane before being converted to diversified agricultural uses. The green and purple regions together comprise a reasonable estimate of the lands to be retained in the proposed new Agricultural District. Much of the new Agricultural District on the Big Island of Hawaii would consist of these medium-quality lands, reflecting the lack of high-quality soils.

The yellow regions, with LESA scores below the IAL cutoff, represent poor agricultural lands. These lands generally contain gullies and ridges and either lie fallow or are used for low-intensity grazing. Many of these lands (69 percent) are located on the island of Hawaii, and they would be excluded from the Agricultural District if the LESA Commission recommendations are followed. These lands would be less protected by Hawaii's land use regulatory system, but farming would still be a permitted use.

V. LEGISLATIVE ISSUES

A number of bills have been introduced in the Hawaii Legislature involving the implementation of the LESA Commission recommendations. All involve a LESA-type system for rating the agricultural quality of land, and a major downsizing of the present Agricultural District. The more important issues are discussed below.[5]

Classification of Land Excluded from the Agricultural District

The most controversial issue in LESA-related legislation is the disposition and control of land currently in the Agricultural District that would be excluded from the reformed Agricultural District.

4 The LESA Commission proposed that the new Agricultural District be called the IAL District. IAL therefore can refer to both a provisional inventory of good agricultural land, or to the proposed new Agricultural District. However, several of the legislative proposals to implement LESA do not use the term IAL.

5 Confidential interviews with government officials provided information and concerns discussed in this section.

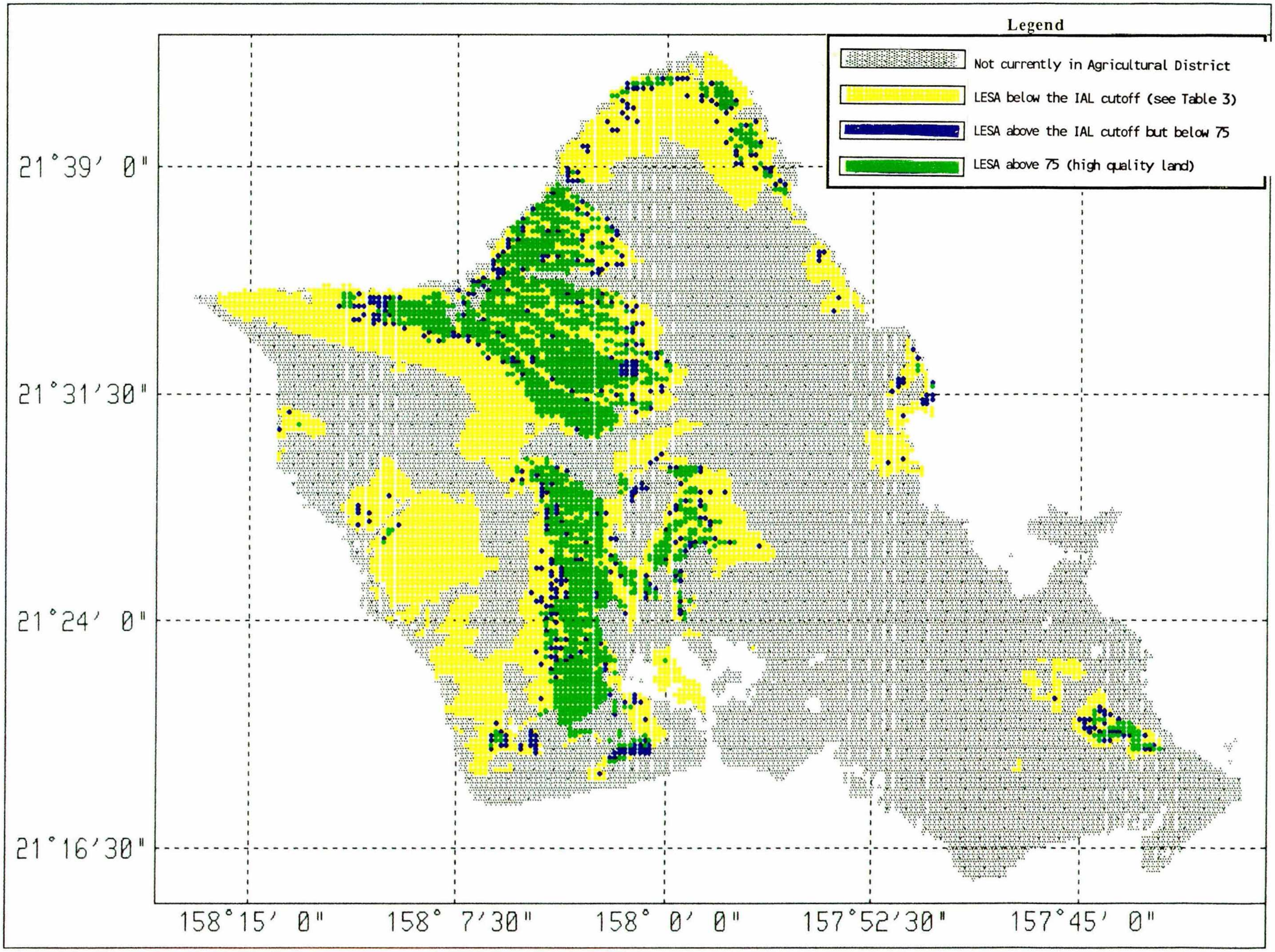
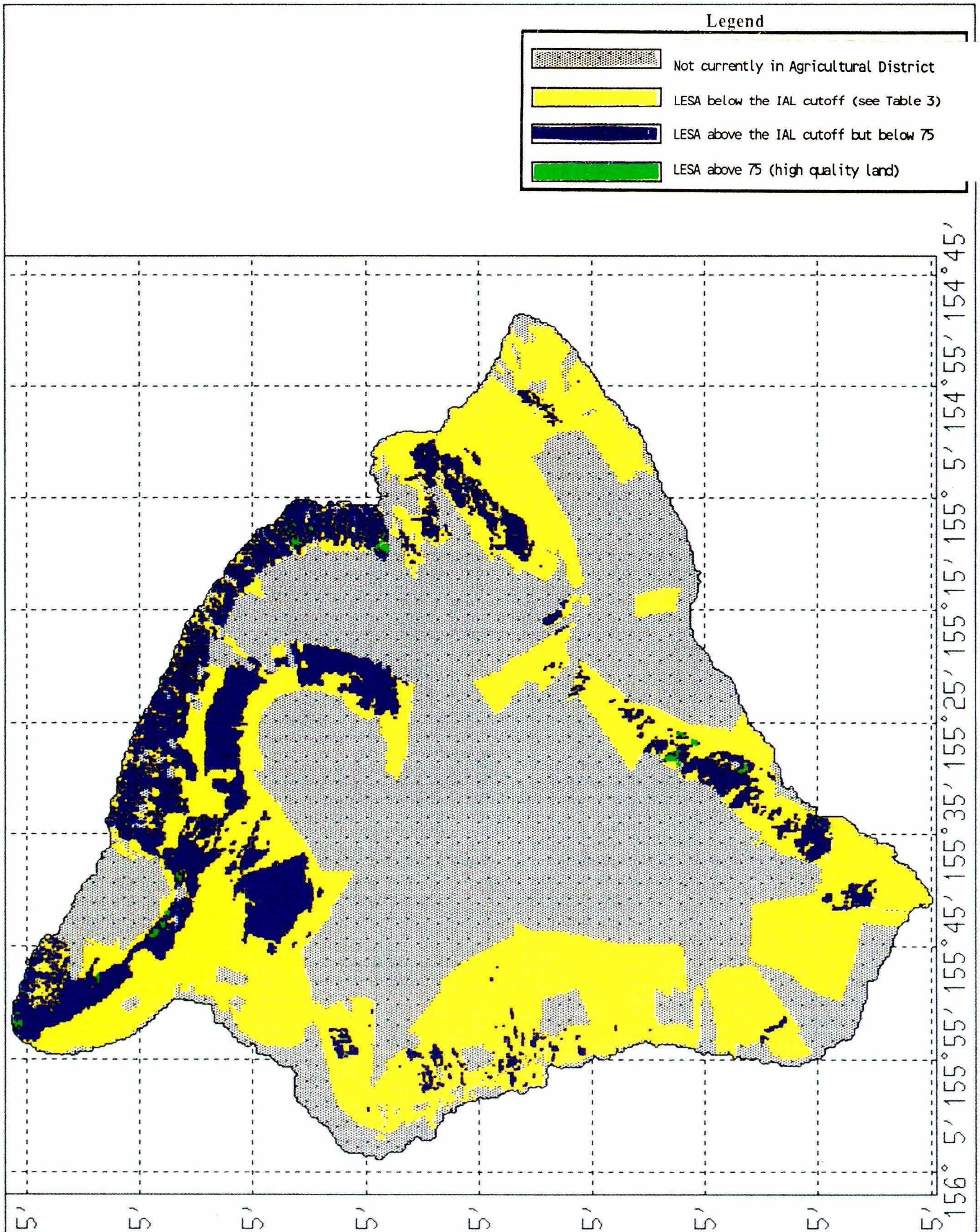


Figure 1. Map of LESA Scores - Oahu

Figure 2. Map of LESA Scores - Hawaii



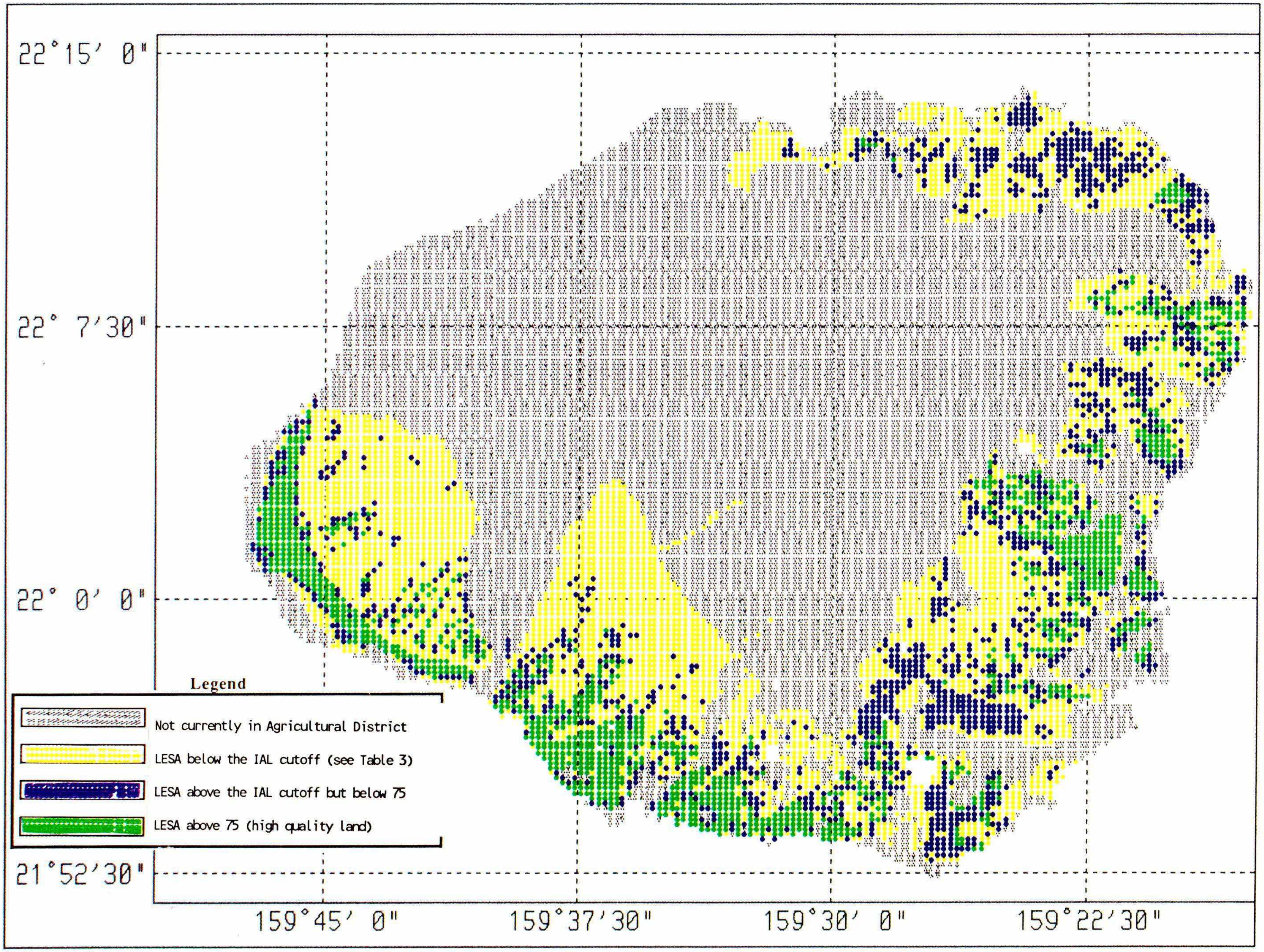


Figure 3. Map of LESA Scores - Kauai

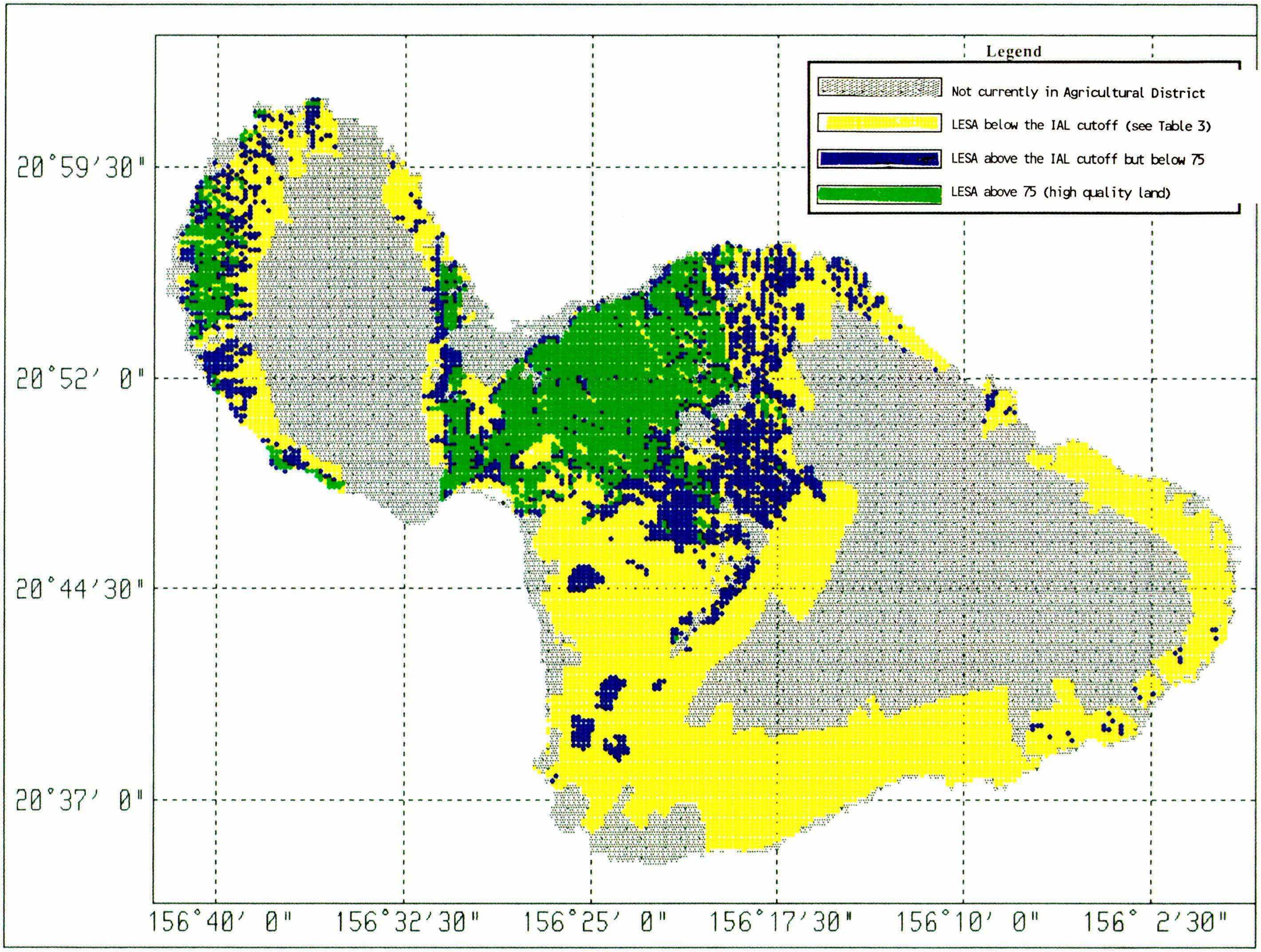
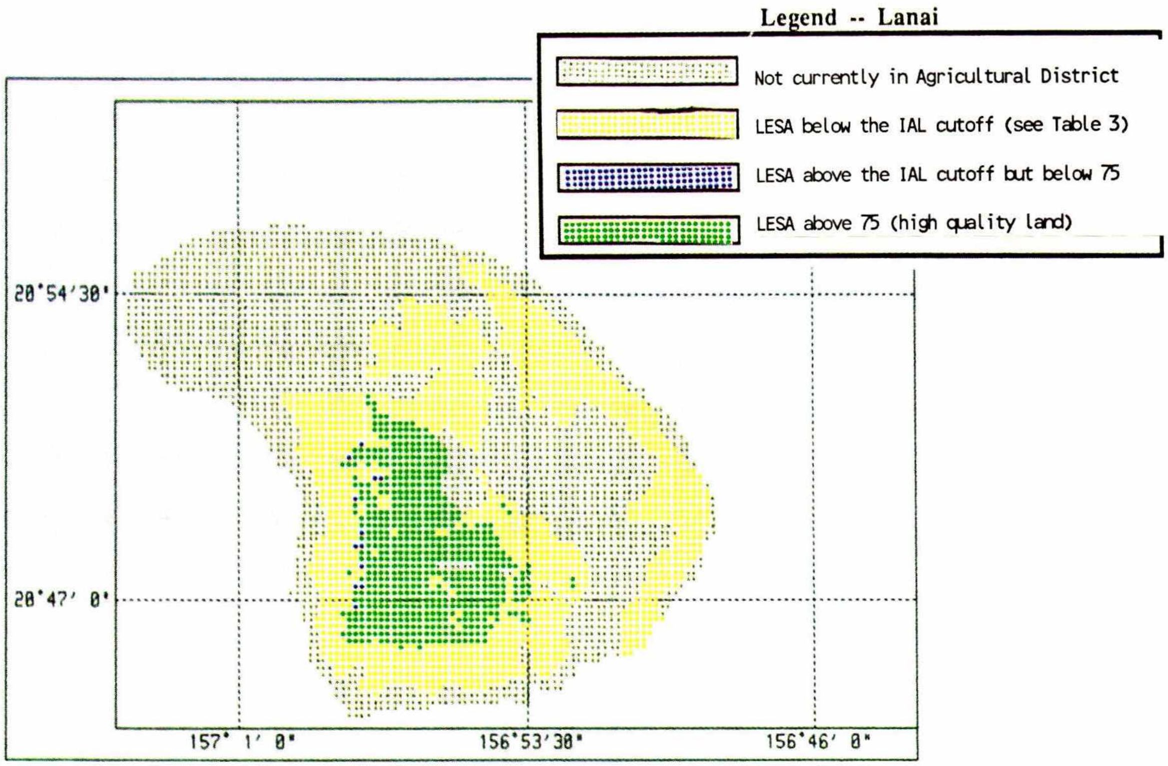
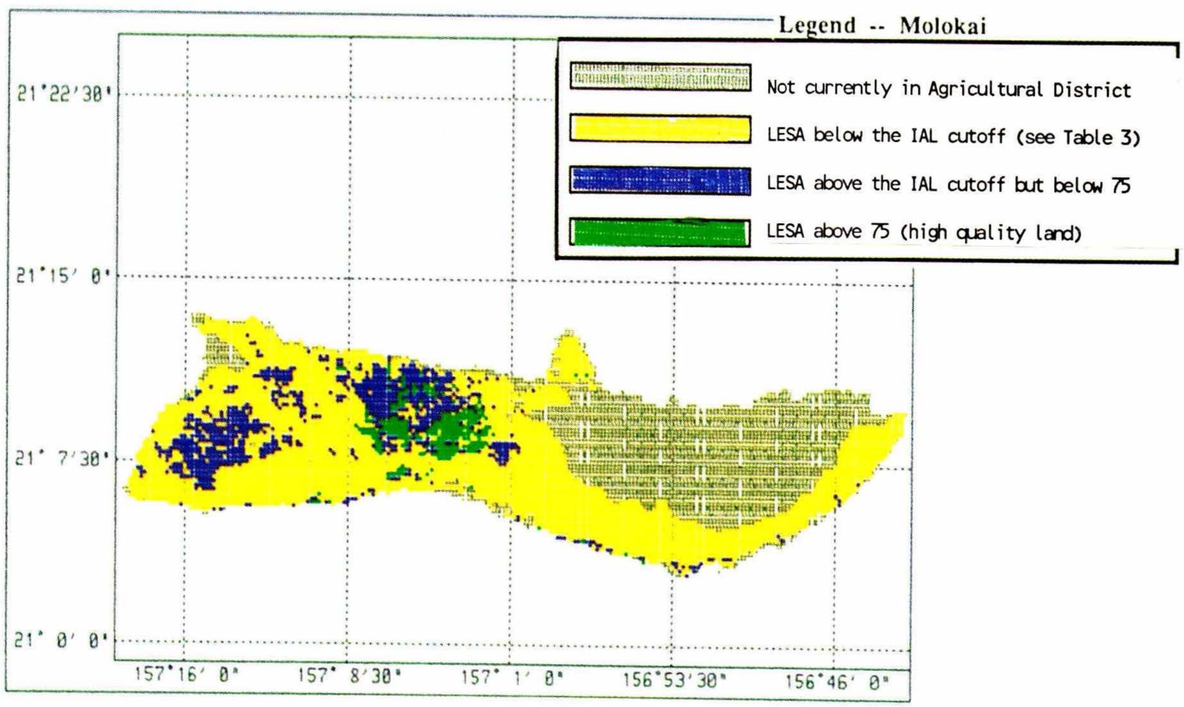


Figure 4. Map of LESA Scores - Maui

Figure 5. Map of LESA Scores - Lanai and Molokai





The LESA Commission recommended that these lands be placed in an "Other Lands" District, which would be regulated like the present Urban District, i.e., under exclusive control of the counties. Since this involves a substantial increase in the land controlled by the counties, county officials and other supporters of greater "home rule" have supported this recommendation.

The Office of State Planning has proposed that most of these lands be placed in a new "Open" District, which instead would be jointly managed by the state and counties. The justification given for this approach is that county governments view their local counties as autonomous systems, rather than as part of an integrated statewide economic system. Counties may engage in undesirable, competitive development activity, which can be limited by statewide growth management. The state government has statewide responsibilities for economic development, education, and the provision of other social services and therefore ought to be concerned with, and provide leadership for, statewide growth management. State officials acknowledge that county planning staffs are technically sophisticated but charge that their perspective is too narrow.

Figure 6 shows the distribution of land by current land use districts, as proposed by the Office of State Planning, and as recommended by the LESA Commission.

Use of the Site Assessment Component of LESA

The Site Assessment (SA) component of the Hawaii LESA system has been controversial because of differences in opinion over the relative importance of individual SA factors and ambiguous factor definitions. In addition to problems in defining and mapping SA factors, certain factors may lead landowners or lessees to engage in undesirable, reactive land use strategies in order to minimize LESA scores on their land. An example is SA factor 4, 'Availability of Irrigation Water'. An agricultural producer considering the installation of an irrigation system might cancel such plans in order to retain lower LESA scores. Lower scores would increase the likelihood of government approval to convert these agricultural lands to urban use in the future should the owner so desire.

Two different approaches to the use of SA have been proposed since the final report of the LESA Commission. One approach is to reduce the number of SA factors, eliminating those factors difficult to define or map, or which may induce reactive behavior. Another approach is to totally eliminate SA, and rely exclusively on the Land Evaluation (LE) scores. The implications of this issue are further discussed in Section V.

Inclusion of Unique Lands

The LESA Commission recommended that an additional 18,483 acres (1990 requirement) of Unique Lands be incorporated into the new Agricultural District. The Commission identified six "unique" commodities for which it established state production goals. But the Commission staff never mapped these unique lands. Some legislative proposals have omitted reference to Unique Lands, while others have specified that those lands identified by the LESA Commission be included. The problem of identifying Unique Lands is discussed in Section V.

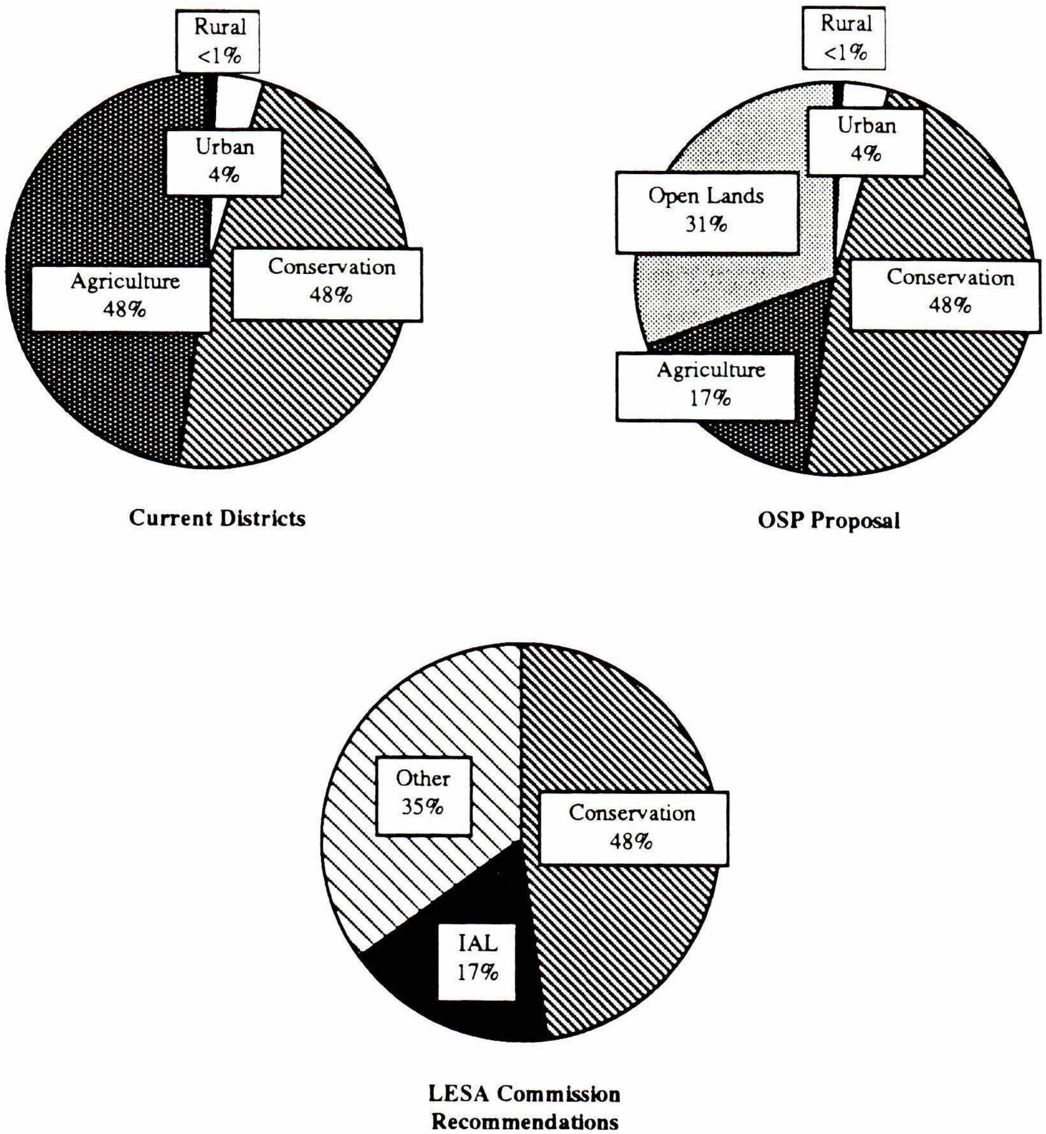
Administration of the Agricultural District

Current administration of the Agricultural District gives considerable leeway to the counties. There are no statewide infrastructure standards, and the counties may issue special permits for activities not defined in the Land Use Law. Since lands unsuited to agriculture were to be excluded from the reformed Agricultural District, the LESA Commission believed that tighter administration of the Agricultural District was desirable.

The Commission recommended that the state Department of Agriculture (DOA) in consultation with the LUC, establish permitted uses. Additionally, the DOA, in consultation with the counties, would establish statewide standards for the required infrastructure in the Agricultural District. The counties, in consultation with the DOA, would administer the permitted uses, infrastructure standards and other regulatory functions. Thus, the state would maintain uniformity among the counties in permitted uses and infrastructure standards, but the day-to-day administration would remain with the counties. Some legislative proposals have attempted to implement this proposed system while others would not substantially alter the present administrative arrangements.

The LESA Commission believed that proposed reclassification of large parcels, like those for resorts and urban subdivisions, required detailed state review. For small parcels, however, the Commission held that redesignations should not be subjected to the long and costly quasi-judicial contested case method used by the Land Use Commission (LUC). However, the LESA Commission could not reach a consensus on the appropriate method for redesignating small parcels. The major legislative alternatives have been either to require that all parcels be subject to LUC approval, or to allow

Figure 6. Relative Size of State Land Use Districts Under Current and Proposed Redistricting Approaches



redesignations of parcels of 15 acres or less to be decided by the counties.

Replacement of Reclassified Agricultural District Lands

The LESA Commission envisioned that lands taken out of the reformed Agricultural District would be replaced by lands reclassified from another district, unless agricultural production goals were reduced accordingly. The mechanism for replacing Agricultural District lands was not specified. Only one legislative bill introduced to date has attempted to implement this policy. It required a successful petitioner taking land out of the Agricultural District to locate and upgrade the LESA score on non-Agricultural District lands so that the LESA scores for replacement land are comparable to or higher than the LESA scores of land being removed.

Coastal Lands

One legislative bill has proposed that all lands within 1,000 yards of the shoreline be excluded from the new Agricultural District. The rationale for this proposal is that coastal lands are ideally suited to resort, housing, or open space usage. The agricultural potential of these lands should not be a barrier to conversion to higher valued uses. Removal of these lands from the Agricultural District could substantially reduce the conflict between agriculture and open space or urban development.

V. EVALUATING LESA REFORMS: THE CASE OF OAHU

Criteria for Evaluating LESA-Related Reforms

The appropriate criteria for evaluating the LESA rating methodology depend upon the uses for which the system is designed. LESA can be used for many purposes, including agricultural components of environmental impact studies, tax assessment, and identification of lands for purposes of zoning. In Hawaii, there are two potential applications, both related to use in zoning.

One proposed use of the Hawaii LESA system is to identify the lands to be taken out of the present Agricultural District and those to be retained in a reformed Agricultural District as a one-time process to shrink the Agricultural District. The LESA system could also be used in succeeding five-year boundary reviews, to review all lands for possible reclassification. For this type of use, LESA scores would be applied to large areas of land.

A second use is to evaluate individual petitions to reclassify land in the Agricultural District. This differs from the first use in that relatively small parcels of land are under scrutiny. The information needs for case applications are much less than for statewide assessment.

Four evaluation criteria are proposed for evaluating LESA-related land use regulatory reform: (1) ease of use, (2) objectivity, (3) consistency/non-manipulability, and (4) adaptability. The intended uses of LESA affect the manner in which these evaluation criteria are applied.

Ease of use is important for all potential users of the LESA system. If the system is difficult to use, then additional costs will be imposed on users and the dissatisfaction could lead to the system being terminated. An ideal LESA system should be low cost, readily available to potential users, and have clear, detailed explanations for use of the system. Factors would be unambiguously defined, easy to map, and would not require frequent or expensive updating. The LESA system should also be able to generate maps necessary for boundary reviews.

LESA systems are intended to be **objective** indicators of agricultural suitability. Objectivity is important so that decision-makers have confidence that the system is performing in a reasonable and equitable manner. A LESA system will not be approved or continue to function when decision-makers believe that it is not objective. To be objective, the system should utilize measurable factors with available quantitative data to calculate scores. Ideally, all factors determining the agricultural suitability of land would be included in a LESA system, but as a practical matter only the most important, measurable factors can be accommodated.

A LESA system should be **consistently applied** and **not subject to manipulation.** Legal challenges can result where zoning decisions are imposed in an arbitrary or capricious manner. A consistent LESA rating system would lead any two individuals to give identical scores to the same parcel. Consistency would therefore require clear and unalterable factor definitions. The interpretation of LESA scores should also be consistent. LESA systems used for zoning should not create incentives or loopholes for score manipulation, otherwise unintended actions will be encouraged.

Finally, a LESA system should be **adaptable,** because social and economic conditions change and these changes impact the suitability of land for agriculture. The agricultural production goals and target acreages for each county and the Site Assessment scores for individual parcels can change significantly in only a few years. Also, experience in using LESA will likely produce proposals to improve its functioning. An ideal LESA system would include a mechanism for periodic revision, including feedback from past experience.

Definitional Problems

In developing the Hawaii LESA system, the process of preparing maps revealed some problems underlying many SA factors. Some factors were vaguely defined or unclear and could not be objectively scored. Other factors had clear definitions and could be objectively scored , but source data for mapping were either inadequate or of poor quality. As discussed in Section III, an *ad hoc* committee clarified and, in some cases, altered the definitions of the SA factors to permit mapping. Table 4 summarizes the definitional and data quality problems of the SA component.

Table 4. Summary Evaluation of Site Assessment Factors

LESA Commission Criteria	Evaluation LESA Commission Intent	Mapping Definition	Quality of Data For Mapping
Conformance with Designation on County plans	Clear	Clear	Good
Availability of Irrigation Water	Clear	Clear, but not precise	Poor
Proximity to Urban Infrastructure and Services	Clear	Clear	Good
On-Site Capital Improvements	Clear	Clear	Uncertain quality; dated
Conflicts with State Projects/Programs	Vague; no definition of "conflict"	Poor proxy; uses narrow definition	Good for the proxy chosen
Access to Off-Site Agricultural Facilities/Services	Clear; but of questionable importance	Clear	Good; easy to map
Parcel Size, Configuration, Location, Etc.	Unclear; no definition of "adaptable and integrated"	Clear, but narrow definition of parcel size	Good
Compatible Agricultural Uses in Area	Vague; no definition of "compatible"	Questionable proxy	Good
Off-Site Drainage Facilities	Clear	Reasonable proxy	Poor
Impact of Non-Agricultural Uses in Area	Vague; no definition of "adverse effect"	Questionable proxy	Good

Source: *Ad hoc* committee of authors and representatives from the Hawaii Office of State Planning and Department of Agriculture.

The first four SA factors in Table 4 were deemed important by the LESA Commission, the Commission's intent for each of these factors was clear, and suitable mapping definitions were developed. Additional improvements could still be made by including seasonality and cost of water in the definition of the Irrigation SA factor, and by including intensive livestock operations in the Farm Facilities factor. Also, the quality of maps for these two factors were either poor or somewhat dated.

Concerns about the other six SA factors include their importance, and distortions in the Commission's intent in developing alternate definitions which could be mapped. The constraints of time and budget did not permit the development of suitable mapping definitions in some cases. As an example, the Conflicts with State Projects/ Programs factor would seemingly require that numerous state plans and reports be reviewed to determine the potential effect on Agricultural District lands. Instead, state-owned lands were mapped for this factor. State lands were rated high as to agricultural suitability and all other lands rated low. Deficiencies in this definition are rather apparent.

Mapping of Unique Lands has been completed only for wetland crops (i.e., aquaculture, taro, water-cress) and for coffee (i.e., Kona coffee) because these lands are identifiable and relatively scarce. Identifying Unique Lands to support papaya and flowers/nursery is more difficult because these crops can be cultivated in many areas of the state.

Defining unique coffee lands may become a problem in the future if present pilot plantings on several islands produce high quality coffee. Kona coffee has achieved a"gourmet" status. Some new producers are targeting the "premium" coffee market, which is of lower status than gourmet coffee but has a much larger market. The LESA system may need future updating to recognize such changes in markets and production. The development of other high quality or exotic agricultural crops in Hawaii may also create a need to modify the definition of Unique Lands.

Important LESA Factors

To further assess the suitability of the Hawaii LESA system, statistical analyses investigated the various model components and use of LESA scores for state zoning. At the time the analyses were performed, digitized maps including all ten SA factors were complete only for the island of Oahu, so analysis was limited to lands now in the Oahu Agricultural District. The Oahu analysis and results are summarized in this and the following subsections. More detailed explanations are given in the Appendix.

Initial analysis considered the statistical correlation among LE and SA factor ratings and scores to measure their relative importance in determining the overall LESA scores. The purpose was to identify factors which could be eliminated from the model without significantly affecting the results, thereby increasing the ease of using the system and reducing data collection and digitizing costs.

Correlations for the LE component found all five LE factors provide closely related measures of agricultural land productivity. Any two factors taken together can account for at least 95 percent of the overall LE rating. Since LE ratings are based on soil types, which have already been incorporated into the HNRIS database, there is no immediate advantage in reducing the number of LE factors in the Hawaii system. However, these results do indicate that the LE factor weighting has little impact on the relative LE ratings.

Correlation results for the SA component presented a somewhat different picture than LE. Individual SA factors were not as closely correlated with each, nor with the overall SA score. However, when factors were combined, certain groups of factors were able to achieve a much higher degree of correlation. In particular, a combination of the first four factors listed in Table 2 (County Plan, Irrigation, Urban and Farm Facilities) accounts for 95 percent of the overall SA score. These results gave the first indication of possible simplification in the LESA system, which is pursued in the next subsection.

IAL Sensitivity to Changes in the System

The second portion of the Oahu analysis explored the sensitivity of the IAL District identified by the LESA system to changes in the numeric values set by the Commission for SA factor weights, the relative LE:SA ratio, and the IAL acreage target. The generalized LESA system allows for considerable local discretion such that specific numbers may be subject to question. In the analysis, each system parameter was separately raised and lowered from the base values set by the LESA Commission. New LESA scores and/or IAL cutoffs were then computed, and the resulting IAL compared with the base district.

IAL sensitivity was first tested for moderate changes in the SA factor weights, typically plus and/or minus one step in the LESA Commission's weighting scale. Table 5 lists the weights for the different SA factors. Total LESA scores proved relatively insensitive to such changes in the SA factor weights.[6] As shown in the same table, only 3 percent of the baseline IAL District is reclassified as unimportant lands under alternative weighting schemes.

These results, when combined with the SA correlation analysis, indicate a large potential to simplify the Hawaii LESA system by equalizing the weights for the first four SA factors and eliminating the remaining six factors from the model, as has been proposed in one legislative bill. This simplification would greatly reduce the difficulty and costs of HNRIS mapping because, for the first four SA factors, the intent of the LESA Commission criteria is relatively clear and good mappable data are available or can be developed. This approach would not significantly change LESA system output. A four-SA factor model with equal SA weights can account for 98 percent of the differences in the baseline LESA scores, and would reclassify only 3

[6] Earlier correlations analysis found that SA factors with base weights of 1 or 4 had only marginal impacts on LESA scores. For these factors, the alternative weight used in the sensitivity analysis was raised to 7 in order to generate noticeable differences.

percent of the original IAL area.

Sensitivity of the IAL District to the LE:SA ratio used to combine the system's two major components considered three alternative ratios: 1:0, 1:2 and 1:3. There was only a small statistical correlation between the overall LE and SA ratings, such that LESA scores and the IAL identified were more sensitive to changes in the LE:SA ratio than the SA factor weights. The impact of alternative ratios is shown at the bottom of Table 5.

Table 5. Sensitivity of Oahu Important Agricultural Lands (IAL) to Changes in LESA System Parameter Values

System Parameter	Parameter Value: Base	Parameter Value: Alternative	Sensitive Acreage (a)
			% base IAL
SA Factor Weights			
County Plan	15	10	2%
Irrigation	10	15	1
		7	1
Urban Facilities	7	10	1
		4	1
Farm Facilities	7	10	1
		4	1
State Programs	7	10	< 1
		4	3
Agricultural Services	4	7	1
Farm Layout	4	7	1
Compatible Use	4	7	2
Drainage	1	7	1
Non-Agricultural Use	1	7	1
No.(Weights) of SA Factors(b)	10 (base)	4 (equal)	3%
LE:SA Ratio	1:1	1:0	12%
		1:2	4
		1:3	8

(a) Lands classified as IAL under base LESA system (10 SA factors, base SA factor weights, 1:1 LE:SA ratio) which reclassified as non-IAL using alternative parameter value.

(b) Base weights shown in upper portion of table. Alternative includes only first 4 SA factors listed.

Increasing the relative weight given to SA, the 1:2 and 1:3 ratios transfer some IAL in Central Oahu and Ewa away from developed to more outlying areas. Coastal IAL also move inland. More importantly, raising the LE:SA ratio beyond the 1:1 recommended by the LESA Commission would likely undermine the constitutional mandate to protect agricultural land. The higher ratios bring into the IAL very low productivity lands with overall LE ratings as low as 12, the minimum score for Oahu. Such an IAL District probably could not meet the crop production targets set by the commission.

The base 1:1 ratio and 1:0 ratio or LE-Only system are plausible alternatives. Dropping SA from the model involves reclassifying 12 percent of the base IAL District. These areas are shown in Figure 7, along with the replacement lands that would be brought into the IAL to satisfy the acreage target. With an LE-Only model, the largest shifts out of the IAL are from the Ewa plain, and from lands around or south of Waialua. Other IAL losses occur in Central Oahu south of Wahiawa, in the center of the plateau lying between the Waianae and Koolau Ranges. Replacement IAL acreage arises around the edge of the plateau closer to the rise of the mountains, on the North Shore and northern areas of the Windward Coast above Waiahole, and among more inland areas of the leeward side of the island. An LE-Only system therefore would move some agricultural activity away from the present concentration of crop production in Ewa and Central Oahu.

The last sensitivity analysis performed changed the size of the IAL District from the base 55,900 acres. The IAL target was increased and decreased to 65,000 and 45,000 acres, respectively. The new targets caused substantial changes in the cutoff LE-SA score from the baseline score of 68, which defines the IAL. The lower acreage target raised the cutoff score to 74, and the higher acreage target caused the cutoff score to fall to 61. The differing targets and cutoffs, however, do not radically change the configuration of the IAL District. Increasing the target simply adds more land around the district periphery, with a majority of IAL acreage remaining in Central Oahu, North Shore and Ewa. Most IAL areas on Oahu are inland, therefore exclusion of coastal lands from the IAL district, as has been proposed in the legislature, would not greatly affect Oahu's IAL.

Using LESA for Boundary Amendment Petitions

Besides redefining boundaries to shrink the Agricultural District, the LESA Commission recommended using the LESA system to review petitions for land-use boundary amendments. In proposals submitted to the legislature since the Commission's report, the state Land Use Commission (LUC) would perform such reviews. Use of the Hawaii LESA system to review petitions was tested for three sites on Oahu (location and size given in parentheses): Kapolei Village (Ewa, 820 acres), Mililani-Mauka (Central Oahu, 723 acres), Village Park Expansion (Waipahu, 547 acres). These sites, chosen from recent LUC petitions for Urban redisricting, are in agricultural areas facing strong pressures for land-use conversion. All received LUC approval for reclassification to the Urban District and housing development.

The base LESA system recommended by the LESA Commission was used to evaluate the agricultural potential of the three case study sites. Maps of site boundaries were obtained from the LUC, digitized into HNRIS, and merged with the existing database to determine LESA scores for areas within each site. Given the rather large project sizes, all three sites showed considerable variation in scores within the site. The Hawaii LESA Commission did not address this possibility, implicitly assuming a project under review would have a single score. (The Appendix contains a more detailed discussion of the distribution of scores within sites).

With multiple scores for individual sites, there are several LESA-based criteria which could be used to evaluate the relative agricultural potential of the overall project area. The national LESA handbook (USDA,1983) recommends using the mean LESA score. However, given the asymmetry of score distributions, the median might provide a better measure. It is also less susceptible to manipulation by developers, who could lower a mean score by extending project boundaries to include very poor quality lands. A third possible criterion is the percentage of site acreage within the IAL district This utilizes the LESA Commission policy framework of districting sufficient agricultural land to meet specified crop production targets.

Another issue relates to the County Plan SA factor. To convert agricultural land to an urban use, a developer must obtain approval from both the LUC and the county zoning board. The latter

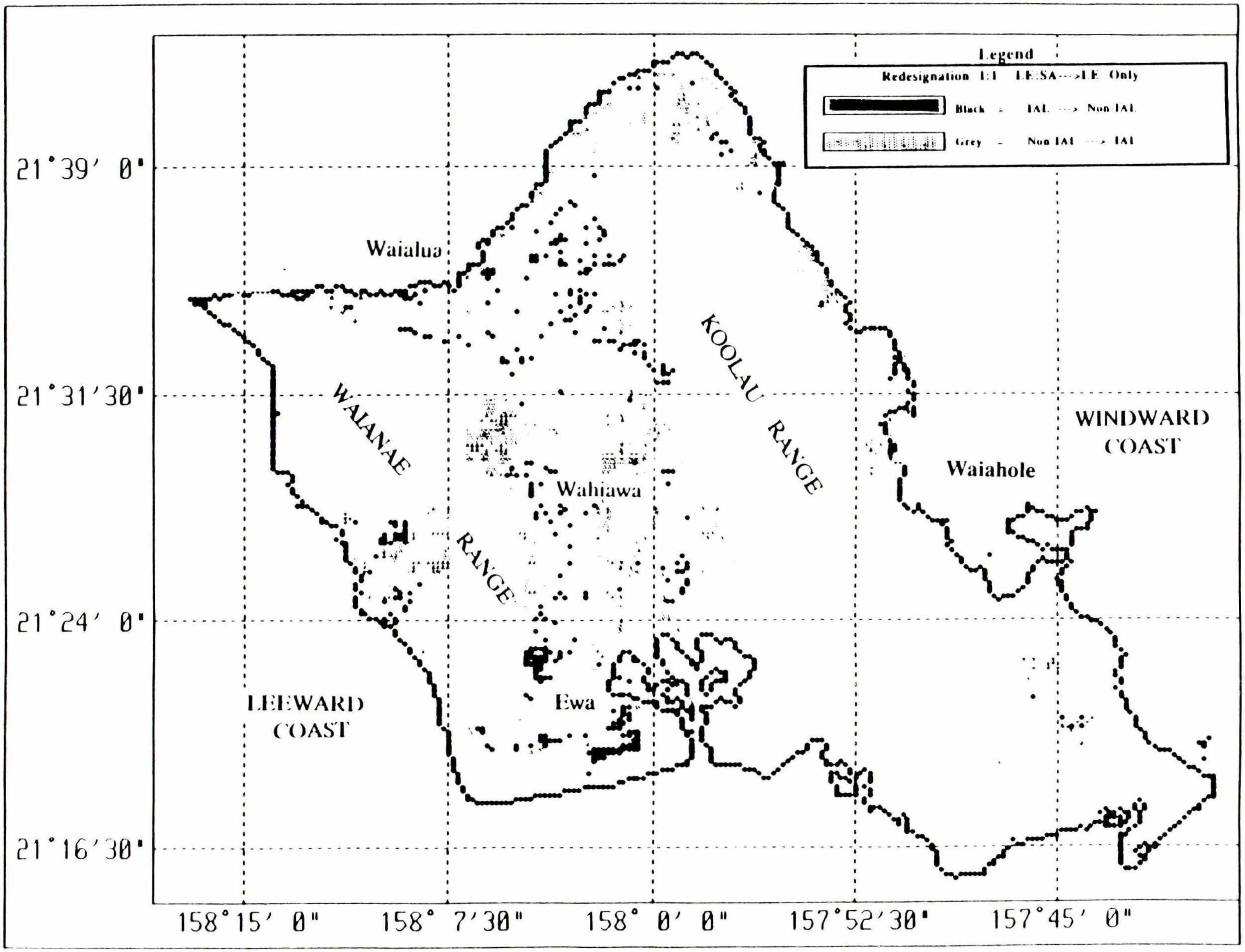


Figure 7. Map of Oahu LE:SA Ratio-Sensitive IAL Lands

action would change the County Plan SA ratings. In the present regulatory system, a developer can apply to either the LUC or the county first, or to both simultaneously. Because the LUC review of a boundary amendment petition may be conducted before or after county rezoning, evaluation of the case study sites was analyzed for two situations. The first, Current County Plan scenario assumed the developer applied first to the LUC, and LESA scores were computed using the current County Plan SA ratings. The alternative Redesignated County Plan scenario assumed the developer had already applied for and received county rezoning approval before petitioning the LUC. In the latter case, the site's County Plan ratings and LESA scores were adjusted to reflect county rezoning.

Table 6 presents statistics and ranking of agricultural potential for the Oahu case study sites. In both County Plan scenarios, the median provides very different rankings as opposed to the other statistical criteria, with Mililani-Mauka rated as the best instead of the worst agricultural site. This raises a potential problem. If the LESA system will be used to review boundary amendment petitions without an explicit criterion, the criterion could change from case to case such that land-use decisions will be inconsistent. This has been one criticism of LUC decision-making in the past (Lowry, *et al.* , 1977).

The impact of the County Plan SA factor is shown in the same table. County rezoning of all three areas together causes an across-the-board decline in LESA scores, but has little effect on the relative ranking of agricultural potential. Only the Percent IAL ranking of Village Park is changed by plan redesignation. However, if only one site was rezoned, the ranking would compare the Redesiginated Plan LESA scores for that site against the original Current Plan scores of the other two sites. In all but one instance (again, Percent IAL of Village Park), the redesignated site would automatically be ranked third under all statistical criteria. This brings up a second potential problem in using LESA for state evaluation of proposed development projects. If County Plan factor ratings are adjusted in response to county zoning changes, LUC review would be redundant. The actual decision would be made at the county level.

Table 6. Effect of Alternative Criteria on the Comparative Ranking of Three Oahu Sites

Agricultural Potential	County Plan, Criteria (a)					
	Current Plan			Redesignated Plan (b)		
Rank	Mean	Median	Percent IAL	Mean	Median	Percent IAL
	Site (c) (LESA score statistic)					
First	Kapolei (80.1)	Miliani-M. (88.7)	Kapolei (95%)	Kapolei (73.0)	Mililani-M. (79.7)	Village Pk. (86%)
Second	Village Pk. (78.0)	Kapolei (82.2)	Village Pk. (86%)	Village Pk. (70.3)	Kapolei (76.2)	Kapolei (79%)
Third	Mililani-M. (77.3)	Village Pk. (80.8)	Mililani-M. (80%)	Mililani-M. (68.5)	Village Pk. (71.8)	Mililani-M. (73%)

(a) Mean and median LESA score (maximum 100 point scale). For Percent IAL, percentage of parcels with LESA scores above 68.02, therefore in the base Important Agricultural Lands (IAL) District.

(b) County Plan SA factor changed to "Other" for parcels currently designated "Agricultural."

(c) Kapolei Village, Village Park Expansion, Mililani-Mauka.

VI. SUMMARY AND CONCLUSIONS

This report has highlighted the lessons learned in implementing the Hawaii LESA system. Statistical analysis of the LESA rating scheme and case studies on Oahu have also contributed to a better understanding of the strengths and weaknesses of the LESA system. A summary assessment of the technical aspects of the Hawaii system is given below in terms of the four evaluation criteria presented in Section V—ease of use, objectivity, consistency, and adaptability.

First, the adopted land rating system should be **easy to use.** Potential users will include the state Land Use Commission (LUC), other government agencies, private landowners and developers. The system recommended by the LESA Commission suffers from vague and/or incomplete definitions for several Site Assessment (SA) factors and for Unique Lands. Clearer descriptions must be developed to avoid confusion and differing interpretation of the Commission's original recommendations. Legislation could accommodate such revisions, plus future refinements and updates, by designating a government agency (e.g., LUC or the Office of State Planning) to maintain the "official" LESA system.

The computerized Hawaii LESA system can quickly generate the maps needed to delineate boundaries of a new and smaller Agricultural District. But the existing system includes more SA factors than are necessary for this purpose. The six SA factors with the lowest weights (last six in the Table 2 list) will have only marginal impacts on Agricultural District boundaries, and should be dropped to simplify the system and reduce mapping costs. Equalizing the weights on the remaining four SA factors would further simplify the system, with little impact on the ranking of agricultural parcels.

The computerized LESA system can also generate enlarged maps and compute LESA scores for specific locations. Since the smallest mapped land unit is 20 acres, this would be inappropriate for small landholdings. Computerized LESA information is of potential value to government planners, property owners or developers of larger parcels, as shown in the case studies discussed. The computerized LESA is based at the University, and is presently not funded to provide such information. If the computerized system is to be part of an official LESA, a support system needs to be developed.

A second desirable feature of a LESA system is **objectivity.** An agricultural rating system should be based on factual data and reflect the important determinants of agricultural land suitability. The LE component does not present a problem in this regard. Analysis of the LESA rating system for Oahu supports the LESA Commission recommendation to combine LE with SA at a 1:1 ratio, rather than the 1:2 or 1:3 ratios commonly used on the mainland. As mentioned above, the current definitions for some SA factors and Unique Lands are deficient. The revised criteria should be based on objective, measurable characteristics. For example, the Farm Facilities SA factor could be defined in terms of the value of on-site capital improvements for crop production.

While clearer definitions will improve objectivity of the system, it may still be difficult to find mappable data for some SA factors. In developing a mapped LESA, this problem lead to use of mapping definitions and data which sometimes distort the original factor meanings. One alternative would be statewide surveys, but this would increase the already high cost of mapping.

A lower cost alternative is to reduce the number of SA factors. The six low-weight SA factors present the greatest problems in finding mapped data. Their deletion from the mapped LESA system would increase objectivity as well as ease of use. However, the omitted factors could affect the evaluation of borderline cases and, in some instances, might even become very important. An example would be a proposed development next to a state agricultural park, where the State Programs factor could be pivotal. To deal with such situations, these six factors should be retained in an unmapped version of the LESA system, to be used in evaluating boundary amendment petitions.

Good mappable data are available or can be developed for the four SA factors with the highest weights—County Plan, Irrigation, Urban Facilities, and Farm Facilities. They represent underlying concerns about farm productivity, conflicts between agricultural land use and adjacent urban areas, and disinvestment or idling of farmland in the path of planned future development. Previous studies have found the latter variables to be major causes of agricultural land conversions (Berry, 1978; Bills, 1988). The LESA Commission also considered these SA factors important by assigning them higher weights. Therefore, it is recommended that the above four SA factors be retained in both the mapped and unmapped versions of the Hawaii LESA system.

As a land use policy tool, any LESA system adopted should promote **consistency** in government decision-making and be **non-manipulable.**

Refinement of SA factor definitions and designation of an official system could increase consistency and reduce the problem of score manipulation by landowners. The SA factor for irrigation provides an example of the latter. The costs of providing irrigation water could be incorporated into the factor definition, such that a landowner could not lower the LESA score by forgoing irrigation where facilities were already available or could be easily installed.

The possibility of score manipulation through the County Plan SA factor is more problematic. Prospective developers of agricultural land will have a definite incentive to obtain county rezoning approval, thereby lowering the County Plan rating and LESA score, before petitioning the LUC for a boundary amendment. Whether such action constitutes "manipulation" depends on the legislative intent. Should the legislature want developers to receive prior county approval, this factor will encourage such behavior. But if the intent is that developers should petition the LUC first, then the County Plan factor is counterproductive.

Another problem concerns LUC review of petitions for larger sites which have multiple LESA scores. For consistent evaluation, the LUC needs guidelines on the reporting and use of LESA scores for these cases. It is suggested that the guidelines include preparation of a map showing the distribution of scores across the site. This would expose any attempted manipulation of the average score by extension of project boundaries to include low-rated agricultural parcels. A map would also be useful in considering possible redesign or downsizing of the project to minimize the negative impacts on agricultural land.

A final consideration in adopting a state LESA system is its **adaptability** to change over time. Designation of a government agency to maintain the LESA system should include authorization to periodically review and revise the system to meet future conditions. This could be done in conjunction with the legally mandated five-year boundary reviews.

Periodic reviews of the LESA system should consider the production goals and acreage targets first set by the LESA Commission, including the crops and targeted acres for Unique Lands. Hawaii agriculture is in transition, where continued declines in acreage devoted to plantation crops have been only partially offset by the growth of diversified agriculture. Land planted to sugarcane and pineapple in 1988 had already fallen below the LESA Commission's 1990 target (HASS, 1988).

Future Agricultural District boundaries should be adaptable to the addition of lands necessary to replace areas removed from the district through boundary amendments, or to meet higher production targets. This could be accomplished by including reserve lands in the initial acreage target. Lands targeted for grazing may already fulfill this need. Without a reserve, the LUC would have to transfer land in to the Agricultural District from other districts. Redistricting would raise difficult legal issues on compensating landowners, should the reclassification lower the property value.

Reviews of the LESA system should also consider further refinement or modification of factor definitions based on problems which may emerge in applying the system, agricultural sector development, or the availability of new and better information. For LE, the greatest need is the development of indices for additional indicator crops. The present system relies heavily on land productivity for sugarcane. The economic and social factors in the SA component could benefit from additional information obtained using the U.S. Census Bureau's TIGER (Topologically Integrated Geographic Encoding and Referencing) system, development of which was completed in 1988 (Marx, 1989). TIGER is a mapped database which links disaggregated census data to specific locations and on a much finer scale than previously available. For example, 1990 population census information will be provided at the block level. This could be utilized in the Hawaii LESA system by adding population density to the Urban Facilities SA factor.

With or without modifications in factor definitions, the mapped version of the LESA system will have to be updated for changes in factor ratings. This applies to LE as well as SA where, for example, the U.S. Soil Conservation Service is now preparing to remap the soils on the Big Island (Lee, 1989). The recommended reduction in the number of mapped factors, plus continued use of computer mapping technology will facilitate the updating.

With further improvements, including the recommendations of this report, the LESA system has the potential to improve decision-making on agricultural land use in Hawaii. No numerical land rating system will be perfect. The test of LESA should not be its limitations, but its ability to provide information within an easy-to-use, objective, consistent and adaptable system necessary for better decisions.

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The following sections supplement the discussion in the main text on the Hawaii LESA system, and the statistical analysis for Oahu's Agricultural District. The latter is divided into two parts: correlation of LE and SA factors, and the distribution of LESA scores for the three case study sites.

Detailed LESA Model

In the Hawaii LESA system, the LE factors are from five soil evaluation systems which use different variables and criteria to rate agricultural land productivity.

In the **Land Capability Classification** (LCC), the eight soil classes (I —VIII, best to worst) are based on the damage and effectiveness of treatments for land limitations due to soil properties (erosion, wetness, internal problems) and climate. The **Soil Potential Index** (1—100 scale, worst to best) is derived from the LCC, with the addition of the costs of overcoming or uncorrectable limitations and the relative yield for an indicator crop.

The **Modified Storie Index** rates land (0—100 scale, worst to best) according to five factors: soil profile; soil texture; slope; salinity, erosion, other soil problems; rainfall. The **Overall Productivity Rating** has five soil classes (A—E) based on soil properties, topography, and climate.

The **ALISH** (Agricultural Lands of Importance to the State of Hawaii) system incorporates the broadest range of factors. Besides the usual soil property and climate variables, growing season, moisture supply, drainage, elevation, slope, crop yields, and input use are also considered. ALISH evaluates land suitability for crop production relative to other agricultural land in the U.S., individual states or localities, establishing four land classes: Prime, most productive from a national perspective; Unique, for special high-value crops produced within a given locale; Other Important, where negative characteristic(s) preclude assignment to a higher class; and Residual lands.

To compute an overall LE rating for a site, the original ratings for three LE factors are first proportionally adjusted to a maximum 100 point scale. For example, Land Capability Classification factors are assigned ratings Class I = 100 points, Class II = 87.5 points, ..., Class VIII = 12.5 points. The Overall Productivity Rating's five soil classes are similarly scaled with Class A = 100 points and Class E = 20 points. For the ALISH system, Prime, Unique, Other Important and Residual lands, receive 100, 75, 50 and 25 points, respectively. The Modified Storie and Soil Potential Indices are already rated on a 0—100 or 1—100 scale, so adjustment of the ratings is not necessary.

The Site Assessment component of the Hawaii LESA system contains ten factors. Table A.1 gives the SA factor ratings and point scores. Overall component scores, LE and SA, are weighted averages of factors, scaled for a maximum 100 point score. For the *j*th parcel, these are computed

$$\bar{LE}_j = \frac{\sum_{i=1}^{5} L_{ij} w_i^L}{\sum_{i=1}^{5} \max(L_i) w_i^L} \times 100$$

$$\bar{SA}_j = \frac{\sum_{i=1}^{10} S_{ij} w_i^S}{\sum_{i=1}^{10} \max(S_i) w_i^S} \times 100$$

where L_{ij}, S_{ij} = *j*th parcel's ratings for the *i* th LE and SA factors, respectively, $w^L{}_i$, $w^S{}_i$ = *i* th factor's weight, and $\max(L_i)$, $\max(S_i)$ = highest possible rating for the *i* th factor. The total LESA score combines LE and SA at a given LE:SA (k_1:k_2) ratio in a second weighted average

$$LESA_j = \frac{k_1 \bar{LE}_j + k_2 \bar{SA}_j}{k_1 + k_2}$$

Factor Correlations

Statistical analysis of LE and SA factor ratings for Oahu's Agricultural District lands first examined the simple correlations among factors, and between individual factors and the overall ratings for the separate components. The degree of correlation was measured by *r*, the simple correlation coefficient.

To determine the effect of dropping factors from the model, multiple correlations were computed for groups of LE and SA factors with the overall rating. The overall LE and SA ratings are just linear combinations of their respective factors, therefore the group of all factors taken together is perfectly correlated with the overall rating. Multiple correlation analysis considered all possible subsets of factors instead of a stepwise procedure, where the latter would be sensitive to the order in which factors were listed. For a given number of

Table A.1 Model Parameters and Descriptive Statistics for Site Assessment

Factor	Weight	Ratings	Points	Oahu Frequency
				% Agricultural District
County Plan	15	Agricultural	7	78%
		Other	1	22
Irrigation	10	Irrigated	7	45%
		Unirrigated	1	55
Urban Facilities	7	Urban District		
		>1/2 mi.	10	86%
		1/4 - 1/2 mi.	5	6
		<1/4 mi.	1	8
Farm Facilities	7	Crop use	10	39%
		Grazing	5	13
		Fallow	1	48
State Programs	7	State land	7	8%
		Other land	1	92
Agricultural Services	4	Harbor <15 mi.	10	8%
		15 - 30 mi.	5	59
		>30 mi.	1	33
Farm Layout	4	Parcel size		
		>100 acres	10	86%
		20 - 100 acres	8	7
		5 - 20 acres	5	3
		0 - 5 acres	1	4
Compatible Use	4	Same crop	10	49%
		Mixed crop	5	2
		Mixed agricultural and other land use	1	49
Drainage	1	No flood hazard	7	96%
		Flood hazard	1	4
Non-Agricultural Use	1`	No special permits	10	99%
		Non-agricultural use		
		<15 acres	5	<1%
		>15 acres	1	1

factors included in the model, complete enumeration would also reveal any factor groupings nearly as correlated as the top combination, which could serve as effective substitutes. Multiple correlations were measured with the squared correlation coefficient, R^2.

The LE factors proved highly collinear, with r ranging between 0.87 and 0.93. In the multiple correlation analysis, combinations of only two LE factors achieved R^2 values of 0.95–0.98. Thus, any further increases in group size produced very small incremental gains.

In contrast to LE, SA factor ratings were not very intercorrelated with the exception of the Farm Facilities and Compatible Use factors, where r=0.82. Given the rating definitions of these two factors, the latter result is to be expected where sugarcane and pineapple, the dominant crops on Oahu, are grown on large, generally contiguous plantations.

Table A.2 presents the multiple correlation coefficients of SA factor groups with the overall SA score, and the factors which appeared in highly correlated combinations. Only four SA factors can explain up to 95% of the variability in SA scores. But unlike LE, the R^2 ranges are very large for small to medium sized groups, and only specific combinations generate the very high correlations. The first four factors listed in Table A.1 consistently provided the highest explanatory power. This is partly a reflection of the SA factor weights, where the first factors are weighted more heavily in the overall score. This is reinforced by the greater relative variability in the ratings of these factors, shown in the Table A.1 frequencies, such that the effective weights are even larger.

Table A.2 Correlation of Site Assessment Factors with the Overall SA Score, Oahu Agricultural District

Number of Factors Combined	R^2 Range (a)	Most Correlated Factors (b)
1	<0.01-0.61	(4)
2	<0.01-0.80	(1), (4) or (8)
3	<0.01-0.90	(1) or (2), (4) or (8)
4	0.01-0.95	(1) or (2), (4), (3) or (8)
5	0.04-0.97	(1) or (2), (4), (3), (8)
6	0.08-0.98	(1) or (2), (3), (4), (8), (5)
7	0.53-0.99	(1) or (2), (3), (4) or (8), (5) or (6)
8	0.72-0.99+	(c)
9	0.85-0.99+	(c)

(a) Range for all possible configurations on the specified number of SA factors with overall SA score.

(b) Those which occur most frequently in combinations with an R^2 within 0.05 of highest R^2 for that number of factors. Factors are listed by the numbers below in order of greatest frequency ("or" denotes equal frequency):

(1)	County Plan	(6)	Agricultural Services
(2)	Irrigation	(7)	Farm Layout
(3)	Urban Facilities	(8)	Compatible Use
(4)	Farm Facilities	(9)	Drainage
(5)	State Programs	(10)	Non-agricultural Use

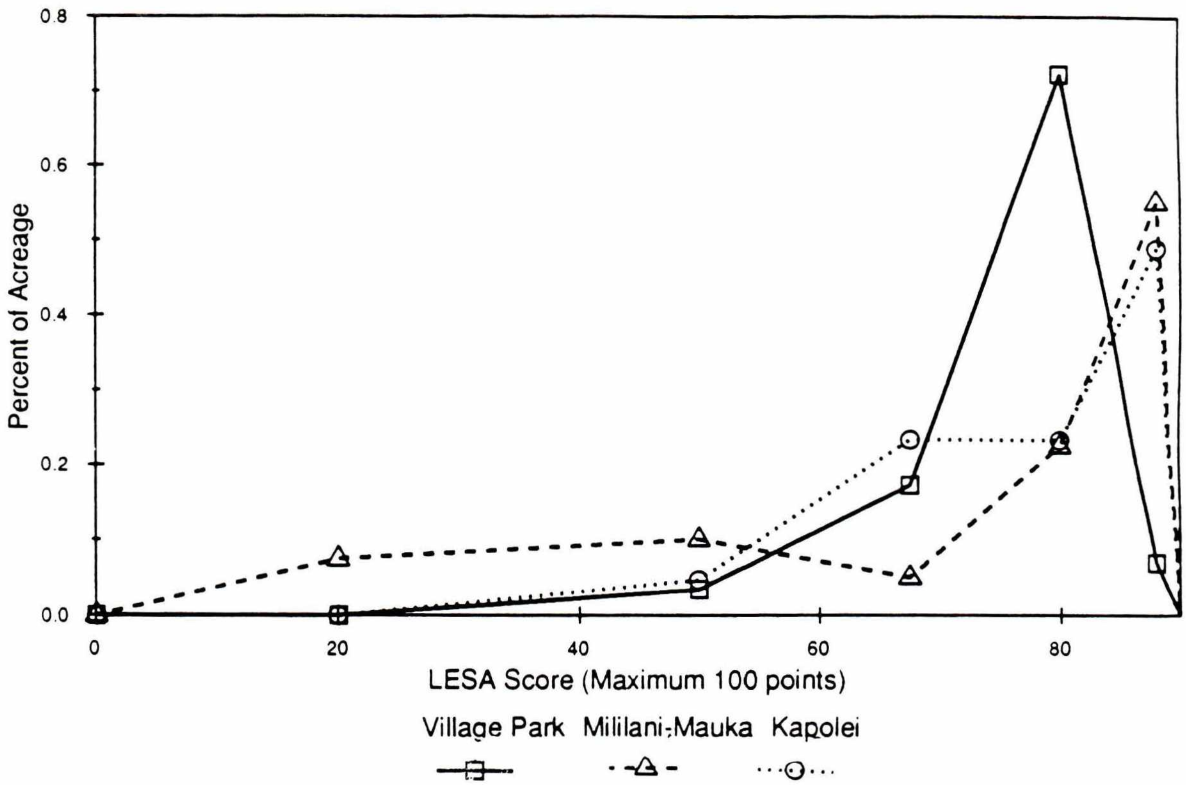
(c) Includes all 10 factors.

Case Study Site LESA Scores

Lands in Oahu's present Agricultural District showed considerable variability in LESA scores. While the mean score is 60, scores for individual parcels ranged from a low of 15 to a high of 96. Similar variations in scores were observed for the three Oahu case study sites.

Figure A.1 presents the frequency distributions of LESA scores for the three sites. All the distributions are very skewed to the left, as is the distribution for the entire Agricultural District. The case study distributions, however, differ noticeably in their degree of skewness and peakedness. As discussed in the main text, these differences are of practical significance, since the relative rankings of agricultural potential vary with the statistic chosen to summarize the distribution. The lack of symmetry in LESA score distributions poses particular problems for the mean, which is more sensitive to these differences and possible manipulation by developers.

Figure A.1 Frequency Distribution of LESA Scores for Three Oahu Case Study Sites



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